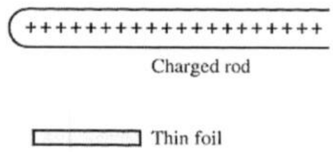
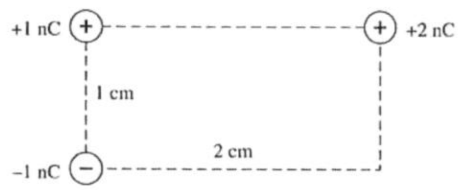
Answer all questions 1-6. Clearly indicate in your answer sheet whether or not you would like the exercise points from spring 2011 to be taken into account when grading the exam. The maximum score of this exam depends on your choice (48/60p corresponding to with exercise points / without exercise points).

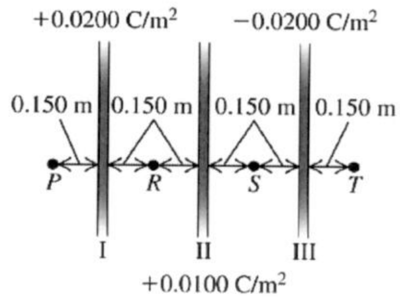
1. (a) Positively charged glass rod is held above a thin aluminum foil whose total charge is zero (see the figure). What happens to the foil? Use text and figures to explain (5p).



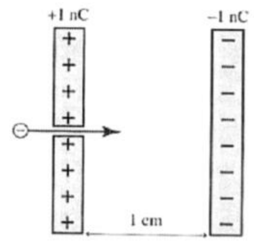
(b) What is the force on + 1 nC charge in the configuration shown below. Remember to give both magnitude and direction. (5p).



2. Three parallel insulator plates possess surface charge densities of $\eta_1 = +0.02$ C/m^2, $\eta_2 = +0.01$ C/m^2 and $\eta_3 = -0.02$ C/m^2 (plates are labeled as I, II ja III in the following figure). Calculate the electric field in points P, R, S and T. Distances between the plates and the location of the points of interest are given in the following figure. (10p)

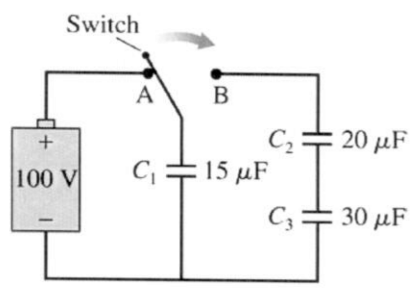


3. Parallel plate capacitor consists of two 10 x 10 cm plates separated by 1 cm distance (you can assume the distance between the plates to be small compared to the area of the plates). The plates are charged to ± 1 nC. A small aperture is then drilled to the center of the positively charged plate and an electron is shot through the aperture towards the negative plate. What is the smallest initial velocity that is required for the electron to reach the negative plate? (10p)



4. Consider a solid insulator ball (radius R= 0.22 m) and assume the ball to be uniformly charged. The electric field generated by this charge distribution at distance $R/2$ measured from the center of the ball is 955 V/m radially outwards.
   (a) What is the total charge of the ball? (6p).
   (b) What is the electric potential at distance $R/2$ measured from the center of the ball (4p).

5. A battery ($\varepsilon = 100$ V), three capacitors ($C_1 = 15$ μF, $C_2 = 20$ μF and $C_3 = 30$ μF) and a switch are arranged as shown in the figure. At first the switch is at position A and the capacitors C_2 and C_3 remain uncharged. Then the switch is thrown

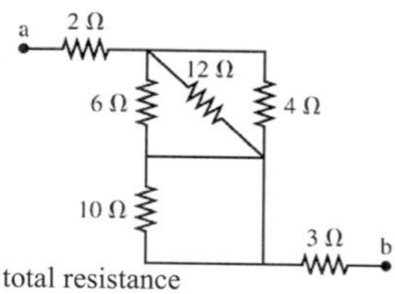


to position B. What is the final charge and voltage of each capacitor (switch at position B)? (10p)

6. Let's consider the circuit shown on right

   (a) What is the total resistance between points a and b (5p)?

   (b) Calculate the power dissipated in the 12 Ω resistor when a 12 V battery is connected between a and b. (5p).



If you did not manage to calculate the answer for 6 (a), use a total resistance of 10 Ω when answering to 6 (b).

$$\vec{E} = \frac{\vec{F}_0}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r} \qquad E = \frac{\eta}{2\varepsilon_0}$$

$$\vec{p} = q\vec{s} \qquad \vec{\tau} = \vec{p}\times\vec{E} \qquad U = -\vec{p}\cdot\vec{E}$$

$$\Phi_e = \oint_A \vec{E}\cdot d\vec{A} = \frac{Q_{\text{in}}}{\varepsilon_0}$$

$$V = \frac{U}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r}$$

$$\Delta V = V_b - V_a = -\int_a^b \vec{E}\cdot d\vec{s} \qquad E = \frac{\Delta V}{d}$$

$$\vec{E} = -\left(\hat{i}\,\frac{\partial V}{\partial x} + \hat{j}\,\frac{\partial V}{\partial y} + \hat{k}\,\frac{\partial V}{\partial z}\right) = -\vec{\nabla}\,V$$

$$C = \frac{Q}{\Delta V} = \varepsilon_0\frac{A}{d} \qquad \varepsilon = \kappa\,\varepsilon_0$$

$$U_C = \frac{Q^2}{2C} = \tfrac{1}{2}C(\Delta V)^2 \qquad u = \tfrac{1}{2}\varepsilon_0 E^2$$

$$I = \frac{dQ}{dt} = n e v_d A \qquad \vec{J} = n e \vec{v}_d$$

$$J = \sigma E \qquad \rho = \frac{1}{\sigma} \qquad R = \rho\,\frac{L}{A}$$

$$\Delta V = R\,I \qquad \Delta V_{\text{P}} = \mathcal{E} - I\,r$$

$$P_{\text{R}} = I^2 R = \frac{\Delta V_{\text{R}}^{\ 2}}{R} \qquad P_{\text{P}} = I\,\Delta V_{\text{P}}$$

$$Q(t) = C\,\mathcal{E}(1 - e^{-t/RC}) \qquad I(t) = I_0\,e^{-t/\tau}$$

$$Q(t) = Q_0 e^{-t/RC} = Q_0 e^{-t/\tau}$$

$c = 2.9979 \times 10^{8}$ m/s
$e = 1.6022 \times 10^{-19}$ C
$\varepsilon_0 = 8.8542 \times 10^{-12}$ F/m
$(4\pi\varepsilon_0)^{-1} = 8.9876 \times 10^{9}$ Nm^2/C^2
$\mu_0 = 4\pi \times 10^{-7}$ H/m
$u = 1.66054 \times 10^{-27}$ kg = 931.49 MeV/c^2
$m_e = 9.1094 \times 10^{-31}$ kg = 0.51100 MeV/c^2
$m_p = 1.6726 \times 10^{-27}$ kg = 938.3 MeV/c^2
$m_n = 1.6749 \times 10^{-27}$ kg = 939.6 MeV/c^2
$h = 6.6261 \times 10^{-34}$ Js = 4.1357×10^{-15} eVs
$R = 8.3145$ J mol^{-1} K^{-1}
$N_A = 6.0221 \times 10^{23}$ mol^{-1}
$k = 1.3807 \times 10^{-23}$ J K^{-1}
$G = 6.673 \times 10^{-11}$ Nm^2/kg^2